

MERCURY TMDL FOR SPRING LAKE IN YELL COUNTY, ARKANSAS

**FINAL
JANUARY 16, 2007**

MERCURY TMDL FOR SPRING LAKE IN
YELL COUNTY, ARKANSAS

Prepared for

EPA Region VI
Water Quality Protection Division
Permits, Oversight, and TMDL Team
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EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to identify waterbodies that are not meeting water quality standards and to develop total maximum daily loads (TMDLs) for those waterbodies. A TMDL is the amount of a pollutant that a waterbody can assimilate without exceeding the established water quality standards for that pollutant. Through a TMDL, pollutant loads can be allocated to point sources and nonpoint sources discharging to the waterbody.

The study area for this project is the Spring Lake watershed in Yell County in west central Arkansas. The study area is part of the Arkansas Department of Environmental Quality (ADEQ) Planning Segment 3G and is located within the Arkansas River Valley ecoregion in Hydrologic Unit 11110204. The study area is located in the Ozark National Forest, and land use in the study area is almost entirely forest.

Spring Lake was included on both the draft and final versions of the 2004 Arkansas 303(d) list as not supporting all designated uses due to a fish consumption advisory for mercury on largemouth bass. The Mercury Action Level in Arkansas for fish consumption advisories is 1 mg/kg of mercury in fish tissue. A mercury concentration of 1.05 mg/kg was measured in largemouth bass from Spring Lake. There have been no known violations of the numeric criterion for mercury in the water in Spring Lake.

The estimated existing mercury load to Spring Lake included atmospheric deposition from local emission sources, regional atmospheric deposition, mercury previously deposited in the watershed and transported to the lake via erosion, and mercury in soils from geologic sources transported to the lake via erosion (background). There are no point sources discharging to Spring Lake. The largest source of mercury to Spring Lake was erosion. The existing mercury load to Spring Lake was estimated to be 0.91 g/day.

The TMDL in this report was developed by assuming a linear relationship between mercury loads to the lake and mercury concentrations in fish tissue. The target fish tissue concentration for the TMDL was 1.0 mg/kg (the Arkansas Mercury Action Level). The total allowable load (equal to the TMDL) was calculated as the existing load (0.91 g/day) multiplied

by a factor equal to 1.00/1.05 (the target fish tissue concentration divided by the measured fish tissue concentration).

The wasteload allocation (WLA) for point source contributions was set to zero because there are no point source discharges to Spring Lake. Ten percent of the TMDL was set aside as an explicit margin of safety (MOS). The remaining portion of the TMDL was assigned to the load allocation (LA) for nonpoint sources. The TMDL and percent reduction needed for nonpoint source loads are summarized in Table ES.1.

Table ES.1. Summary of TMDL and percent reduction.

Waterbody Name	Loads (g/day of mercury)				NPS Percent Reduction Needed
	WLA	LA	MOS	TMDL	
Spring Lake (HUC 11110204)	0	0.77	0.09	0.86	14%

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1.0 INTRODUCTION

This report presents a total maximum daily load (TMDL) for mercury for Spring Lake (HUC 11110204) in Yell County in west central Arkansas. This lake was included on the draft 2004 Arkansas 303(d) list (Arkansas Department of Environmental Quality (ADEQ) 2005) and the final 2004 Arkansas 303(d) list (Environmental Protection Agency (EPA) 2006) because it was considered not to be supporting all designated uses due to fish consumption advisory. This impairment for Spring Lake was erroneously placed in category "4a" of the 2004 303(d) list, which indicates that a TMDL has already been completed. This mistake occurred because EPA approved a mercury TMDL in 2002 for a different Spring Lake in Arkansas (in HUC 11110207). However, no TMDL has been previously developed for mercury in fish tissue for Spring Lake in Yell County (HUC 11110204). The sources of contamination and causes of impairment for Spring Lake from the 2004 303(d) listing are shown below in Table 1.1. The TMDL in this report was developed in accordance with Section 303(d) of the Federal Clean Water Act and EPA's regulations in 40 CFR 130.7.

The purpose of a TMDL is to determine the pollutant loading that a waterbody can assimilate without exceeding the water quality standards for that pollutant and to establish the load reduction that is necessary to meet the standard in a waterbody. The TMDL is the sum of the WLA, the LA, and a margin of safety (MOS). The WLA is the load allocated to point sources of the pollutant of concern. The LA is the load allocated to nonpoint sources, including natural background. The MOS is a percentage of the TMDL that takes into account any lack of knowledge concerning the relationship between pollutant loadings and water quality.

Table 1.1. 303(d) listing for Spring Lake.

HUC	Waterbody Name	Sources	Causes	Category	Priority
11110204	Spring Lake	Unknown	Mercury	4a*	unknown

*Note: As discussed above, this impairment was placed in the wrong category on the 2004 303 (d) list.

2.0 BACKGROUND INFORMATION

2.1 General Information

The study area for this report is the Spring Lake watershed, located in west central Arkansas (see Figure A.1, Appendix A). The Spring Lake watershed is in the Arkansas River Valley ecoregion, in ADEQ Planning Segment 3G. Spring Lake is in US Geological Survey Hydrologic Unit 11110204. Spring Lake watershed covers 17.2 square miles, primarily in Yell County. The lake itself covers 82 acres (ADEQ 2000).

2.2 Soils and Topography

Soil characteristics for the watershed were taken from the Yell County soil survey (USDA 1988). Soils on the slopes in the watershed are generally classified as well drained gravelly and stony soils. Soils in valleys are classified as well drained to poorly drained deep loamy soils. Soil associations that are most common in the watershed include and Enders-Nella-Mountainburg and Leadville-Cane-Taft. Other soil associations that are somewhat common include Carnasaw-Sherless-Clebit and Guthrie-Barling. Soil mercury concentrations that have been measured in Arkansas ranged from 0.1 mg/kg to 0.16 mg/kg (Armstrong et al. 1995).

The topography of this area can be described as level in the flood plains, progressing to rolling flat-topped hills and long narrow ridges with broad valleys with some very steep hillsides.

2.3 Land Use

Land use data for the study area were obtained from the GEOSTOR database, which is maintained by the Center for Advanced Spatial Technology (CAST) at the University of Arkansas at Fayetteville. These data were based on satellite imagery from summer 2004. Land use in the watershed is predominantly forested (Figure A.2, Appendix A) with most of the watershed located within the Ozark National Forest. Approximate percentages of various land use categories in the watershed are summarized in Table 2.1.

Table 2.1. Summary of land use in Spring Lake watershed (CAST 2005)

Land use category	Percent of watershed
Forest	98.8%
Water	0.7%
Barren	<0.01%
Urban and other	0.0%
Pasture	0.5%
Cropland	0.0%
Total	100.0%

2.4 Description of Hydrology

Average annual precipitation at Danville (located south of the watershed) is approximately 48 inches. Mean monthly precipitation totals are shown in Figure 2.1. The mean monthly precipitation is highest in May and lowest in January.

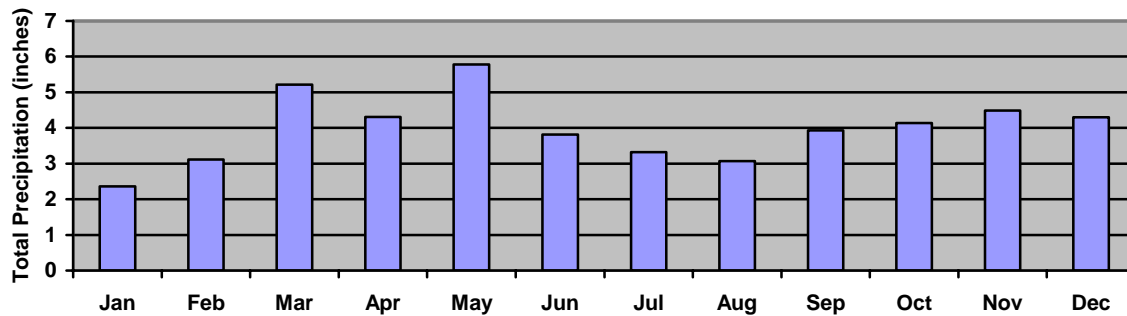


Figure 2.1 Mean monthly total precipitation at Danville, Arkansas.

2.5 Water Quality Standards and Fish Tissue Action Levels

The State of Arkansas has developed water quality standards for waters of the State (APCEC 2006). The standards are defined according to ecoregions and designated uses of the waterbodies. The designated uses for Spring Lake are primary and secondary contact recreation; domestic, agricultural, and industrial water supply; and perennial Arkansas River Valley Fishery.

The numeric water quality criterion for mercury for all ecoregions in Arkansas is 0.012 ug/L, expressed as total recoverable mercury. This water quality criterion is shown in Regulation No. 2 for protection of aquatic life from toxicity, but it was developed to protect

humans from consuming aquatic life contaminated by mercury. There is no correction factor for hardness or other constituent concentrations. The narrative criterion for toxic substances in Section 2.508 (Regulation No. 2, APCEC 2006) is “Toxic substances shall not be present in receiving waters, after mixing, in such quantities as to be toxic to human, animal, plant or aquatic life or to interfere with the normal propagation, growth and survival of the indigenous aquatic biota.”

The mercury fish consumption Action Level in Arkansas is the Food and Drug Administration (FDA) Action Level of 1.0 mg/kg (wet weight). EPA has promulgated a criterion of 0.3 mg/kg (wet weight) for methyl mercury in fish tissues. The EPA criterion has not been used by state agencies in Arkansas.

2.6 Nonpoint Sources

The 2004 Arkansas 303(d) list does not specify a source for the mercury in Spring Lake (ADEQ 2005). Regional and global source mercury atmospheric deposition, and mercury in eroded soils transported to water bodies are potential nonpoint sources of mercury to surface waters.

2.7 Point Sources

A search of the EPA Permit Compliance System (PCS) database did not find any National Pollutant Discharge Elimination System (NPDES) permitted point sources discharging into the Spring Lake watershed.

Information on local air emission sources in the airshed (airshed defined to include counties within 100 km of the watershed boundary, see Figure A.3) was obtained from the 2002 National Emission Inventory (NEI) on the EPA website. NEI data for point sources by county was used. The NEI listed 26 mercury air emission point sources in 8 source categories. A listing of the air emission point sources is included in Appendix B.

2.8 Previous Studies

Spring Lake was one of the lakes sampled by the Arkansas Mercury Task Force in its study of mercury in Arkansas surface waters (Armstrong et al. 1995). Data on fish tissue mercury concentrations, and water quality in the epilimnion and hypolimnion were collected as part of this study effort (Armstrong et al. 1995, Lin and Scott 1996).

Spring Lake is also sampled every five years during ADEQ's survey of Arkansas publicly owned lakes. At each lake, water quality samples are collected from the epilimnion and the hypolimnion, and in situ data are measured. Data from the 1989, 1994, and 1999 sampling events have been published (ADEQ 2000).

3.0 EXISTING WATER QUALITY

3.1 Existing Water Quality Conditions

There have been no measurements of mercury in water at Spring Lake. However, there is a fish consumption advisory for mercury in largemouth bass in Spring Lake. Elevated levels of mercury have not been found in the water of other Arkansas lakes with mercury fish consumption advisories, so it is possible that Spring Lake water mercury levels are also low.

The fish consumption Action Level in Arkansas is based on the FDA guideline of 1 mg/kg. This TMDL uses fish tissue monitoring data as a means to determine whether the “fishable” use is being met and the reductions needed to achieve the designated use. The “fishable” use is not attained if: (1) the fish and wildlife propagation use is impaired and/or (2) if there is a significant human health risk from consuming fish and shellfish resources. Spring Lake was included on the 2004 303(d) List based on elevated fish tissue mercury concentrations. To achieve the designated use, the fish tissue mercury concentration of 1.0 mg/kg should not be exceeded.

3.2 Available Fish and Water Quality Data

Largemouth bass were collected from Spring Lake in 1992 as part of a statewide sampling effort (Armstrong et al. 1995). A mercury concentration of 1.05 mg/kg was measured in this fish sample. ADEQ followed the sampling protocols recommended in *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories*, Vol 1 (EPA 1995).

Water quality data for sulfate, total organic carbon (TOC), and pH were obtained for Spring Lake from the 1999 *Water Quality Assessment of Arkansas' Significant Publicly Owned Lakes* (ADEQ 2000), and Lin and Scott 1996 (Table 3.1). These three constituents have been demonstrated to be correlated with fish mercury concentrations and can affect the bioaccumulation and bioavailability of mercury for methylation and subsequent uptake of methyl mercury through the food chain (Armstrong et al. 1995, EPA 1998). Overlapping ranges of moderate sulfate (5 to 25 mg/L) and TOC (5 to 10 mg/L) concentrations with lower pH values (<5.5 su) provides an environment conducive to microorganisms that methylate mercury

(Armstrong et al. 1995). Several hypolimnion sulfate and TOC measurements from Spring Lake are in the range associated with increased methylation; however, pH values are too high.

No measurements of water mercury concentrations were found for Spring Lake. To estimate the total and methyl mercury concentrations that might be occurring in the water column, the average bioaccumulation factor used in the EPA (1997) Mercury Report to Congress (6.8×10^6) was used to back calculate a water methyl mercury concentration of 0.15 ng/L. The ratio of methyl mercury to total mercury in water ranges from 0.01 to 0.3 (EPA 1998, Krabbenhoft et al. 2000), with systems having enhanced methylation averaging around 0.1. Therefore, a methyl mercury to total mercury ratio of 0.1 was used to estimate a water total mercury concentration of 1.5 ng/L. Both the methyl mercury and total mercury concentrations appeared to be reasonable estimates of concentrations that might be expected in Spring Lake.

Table 3.1. Spring Lake water quality data.

Sample Date	Sulfate, mg/L		TOC, mg/L		pH, su	
	Surface	Hypolimnion	Surface	Hypolimnion	Surface	Hypolimnion
1989	4.0	10.0	1.3	2.4	-	-
1994	3.9	9.9	3.4	6.3	-	-
1999	3.07	3.04	2.17	2.43	6.58	6.73

4.0 DEVELOPMENT OF THE TMDL

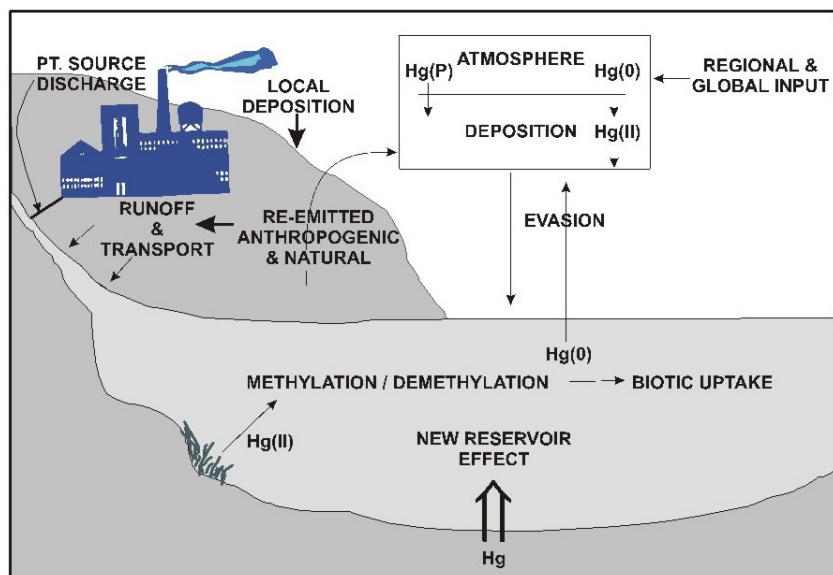
4.1 Loading Capacity

The loading capacity of waterbodies differ based on a site specific basis due to (1) inputs or load of mercury to the waterbody, (2) environmental conditions within the waterbody that mediate methylation and bioaccumulation, and (3) the food web or food chain through which mercury bioaccumulates (Armstrong et al. 1995). Currently, the water body concentrations of mercury and methyl mercury are unknown. In the future, clean sampling and analysis procedures might facilitate the estimation of loading capacity through water column monitoring.

4.2 Conceptual Framework

Mercury is unlike many other metals because it has a volatile phase at ambient temperatures and can be transported in a gaseous, soluble, or particulate form (Figure 4.1). Mercury is emitted to the atmosphere in both elemental gaseous Mercury(0) and divalent Mercury(II) forms. Anthropogenic direct emissions, natural emissions, and indirect re-emission of previously deposited mercury are major sources of mercury to the atmosphere (Figure 4.1). Gaseous Mercury(0) is relatively insoluble and is capable of being transported long distances and contribute to regional and global background concentrations.

Figure 4.1. General mercury cycle showing atmospheric transport and deposition, point, nonpoint source and natural background contributions, and the effects of new reservoirs on mercury release into the environment.



Mercury(II) is much more soluble and can sorb onto particulates, so it tends to be removed from the atmosphere by both wet and dry mercury deposition closer to emission sources, within local (i.e., 100 km from the source, EPA 2001) and regional areas (EPRI 1994). Ozone or other oxidizing agents in the atmosphere can convert Mercury (0) to Mercury (1), and some Mercury(II) can also be chemically reduced to Mercury(0). Mercury(0) can be transported long distances. Local sources of deposited mercury are typically within about a 100 km radius of a site (EPA 2001). Regional sources are loosely defined as other sources within a geographical area such as the Southeast, South, or Upper Midwest, while global sources include intercontinental contributions of mercury. Atmospheric mercury deposition can include contributions from all three sources. In addition to atmospheric deposition, mercury can also enter waterbodies from point source effluent discharges and watershed nonpoint source contributions. These watershed nonpoint sources include both naturally occurring mercury (e.g., geology, soils) and atmospherically deposited mercury that can be transported to the waterbody (Figure 4.1).

The primary mercury species of concern for bioaccumulation and biomagnification through the food chain, however, are not the inorganic mercury species, but the organic, methyl

recent research indicates that inorganic mercury tends to become less likely to be converted to methyl mercury the longer it is in a waterbody (Hintelmann et al. 2002); more recently deposited inorganic mercury is more reactive.

Methylating microorganisms, such as sulfur reducing bacteria, live in anaerobic (zero dissolved oxygen) environments in the sediments of wetlands, streams, rivers, and lakes or reservoirs. New reservoirs (i.e., less than 15 to 20 years old) create environments that are particularly suitable for methylating bacteria so fish tissue mercury concentrations in new reservoirs are typically higher than fish tissue mercury concentrations in older reservoirs.

In summary, TMDLs for mercury must consider that mercury can exist as a gas as well as in solution or particulate forms. Mercury loads arise from atmospheric deposition contributed by both local and regional/global emission sources, point source effluent discharges, natural geological formations, and soils. However, after deposition or loading to the system, it can also be lost through volatilization and re-enter the atmospheric pool. It is the organic form as methyl mercury that is biologically accumulated and magnified through the food chain. Once in fish, it is lost very slowly and continues to accumulate through time.

4.3 TMDL Formulation

A two-phased approach was used to estimate loading capacity and the reductions required to achieve the designated fishable use in the watersheds. In the first phase, mercury loading to Spring Lake was estimated, while in the second phase reductions were estimated based on safe fish tissue Mercury concentrations.

4.3.1 Estimate of Existing Mercury Load

Since there were no known point source discharges in the watershed, the entire estimated mercury load was from nonpoint sources. Nonpoint sources load included regional atmospheric deposition inputs, local emission source contributions, and watershed soil geologic erosional inputs and watershed soil deposited erosional inputs. Estimated loads from these sources are summarized in Table 4.1. The methods used to estimate these loads are described below.

Table 4.1 Estimated existing mercury load to Spring Lake

Source	Annual Load g/yr	Daily Load g/day	Percent of Total Load
Regional Atmospheric Deposition	6.1	0.02	1.8%
Local Atmospheric Deposition	0.8	0.002	0.2%
Soil Deposited Mercury Erosion	202	0.55	61.2%
Soil Geologic Source Mercury	121	0.33	36.8%
Total	330	0.91	100%

4.3.1.1 Regional Atmospheric Deposition

Data for regional atmospheric deposition was obtained from the National Atmospheric Deposition Program (NAPD) website. There are no monitoring stations in the state of Arkansas; therefore, the monitoring station closest to the watershed was utilized (for a map showing locations of all of the NADP monitoring sites, see <http://napd.sws.uiuc.edu/mdn/sites.asp>). Data from monitoring station OK99, in Adair County Oklahoma, were used to represent atmospheric deposition of mercury in the watershed. Data were available from this station for most of 2003 and 2004 through 2005. The average value of the wet deposition was $12.0 \mu\text{g}/\text{m}^2/\text{yr}$. An estimate of the total atmospheric deposition was based on the assumption that dry deposition is about 50 to 60% of wet deposition (Auwarter 2000) resulting in a total regional atmospheric deposition of $19.2 \mu\text{g}/\text{m}^2/\text{yr}$. Wet deposition is the mercury removed from the atmosphere during rain events. Dry deposition is the mercury removed from the atmosphere on dust particles, sorption to vegetation, gaseous uptake by plants, or other input during non-rainfall periods (EPA 1997).

Precipitation data was also available for the OK99 station from the NADP web site. This data was compared with precipitation data from a NOAA meteorologic station at Danville, near Spring Lake watershed. A ratio was obtained by dividing the average annual precipitation at Danville by the average annual precipitation at station OK99. Multiplying the regional atmospheric deposition of $19.2 \mu\text{g}/\text{m}^2/\text{yr}$ by the ratio resulted in a precipitation corrected atmospheric deposition for the watershed of $22.0 \mu\text{g}/\text{m}^2/\text{yr}$. NADP data and NOAA data are shown in Table 4.2.

Table 4.2 Calculation of regional atmospheric mercury deposition in Spring Lake watershed.

NADP Data Summary			Precipitation Data Danville, AR		NADP Data Summary		
Station	Year	Rain Gauge (meters/yr)	Year	Annual Precip. (meters/yr)	Station	Year	Wet Mercury Deposition $\mu\text{g}/\text{m}^2/\text{yr}$
OK99	2003*	0.8	2003	1.1	OK99	2003*	9.5
OK99	2004	1.2	2004	1.3	OK99	2004	12.0
OK99	2005	0.9	2005	0.9	OK99	2005	14.5
Average 1.0			Average 1.1		Average 12.0		
Dry + Wet Deposition = Average Wet Deposition x 1.6 = 19.2 $\mu\text{g}/\text{m}^2/\text{yr}$ Atmospheric Deposition Correction Factor = 1.15 x (Danville Avg. Precip/NADP Rain Gauge Avg.) Precipitation Corrected Atmospheric Deposition Rate = 22.0 $\mu\text{g}/\text{m}^2/\text{yr}$							

*Data available for only part of the year

4.3.1.2 Local Atmospheric Deposition

The OK99 deposition monitoring station includes both local emission sources similar to those in Arkansas and regional/global input. Local atmospheric deposition for Spring Lake was estimated based on data from the 2002 National Emissions Inventory (NEI). The NEI is a complete national inventory of stationary and mobile sources that emit hazardous air pollutants (HAPs). County summaries of NEI point source emissions data from 2002 were downloaded from the NEI web site.

In this TMDL, local sources are defined as sources within the watershed and within a distance of 100 km around the watershed boundary. The area within which these local sources are located is referred to as the “airshed”. The NEI reports sources listed by county, therefore the airshed boundary is determined by county boundaries and if a portion of a county falls within 100 km of the watershed, then the entire county is included as part of the airshed. The airshed boundary for the watershed is shown in Figure 4.4. The mercury emissions for each source found within the airshed are included in Appendix B. Table 4.3 shows the Mercury(II) emissions that contribute to the local atmospheric deposition calculated from the NEI data by source category.

The distance from the emission source, the forms of the mercury in the emissions, other pollutants in the emissions and the atmosphere, and the weather patterns of precipitation and prevailing wind are important factors in determining where mercury released to the air will deposit.

Table 4.3 Calculation of local source atmospheric mercury deposition in Spring Lake

Source Category	Total Mercury Emissions Kg/yr	Speciation Factor	Mercury(II) Emissions, g/yr
Power generation boilers	0.09	0.5	46.3
Industrial boilers	100.02	0.5	50012
Brick manufacture	10.68	0.2	2135
Oil and gas production	0.01	0.2	1.73
Steel Manufacture	98.89	0.2	19777
Pulp and paper production	80.00	0.5	40000
Miscellaneous	0.34	0.5	169
Landfills	0.10	0.2	19.8
Total	290.13 kg/yr		112162 g/yr

Divalent mercury (Mercury(II)) is the dominant form of mercury in both rainfall and most dry deposition processes. An estimate of the Mercury(II) emitted from point sources in the airshed was calculated based on source speciation percentages (EPA 2005a). The mercury deposition rate due to local sources ($2.45 \mu\text{g}/\text{m}^2/\text{yr}$) was determined by dividing the Mercury(II) emissions for the airshed (Table 4.3) by the airshed area ($4.58 \times 10^{10} \text{m}^2$). The global/regional deposition rate was set equal to the precipitation corrected deposition rate minus the local source deposition rate.

The local source and global/regional deposition rates were used to determine the mercury loading to Spring Lake. The area of the lake was multiplied by the mercury deposition rate to obtain a mercury atmospheric load of 6.9 g/yr. Based on the analysis of the local sources, the portion of the mercury deposition that can be attributed to local sources is 0.8 g/yr and to global/regional sources is 6.1 g/yr.

4.3.1.3 Mercury Loading Associated with Soil Erosion

The sediment load for the watershed was calculated using literature erosion rates for forest, pasture, and cropland areas. The land use areas were based on CAST 2004 summer data as presented in Section 2.3. The erosion rate for forest was set to 0.2 tons/acre/year based on information in the Ozark-Ouachita Highlands Assessment Report (USDA FS 1999), which reported erosion rates ranging from 0.2 to 0.8 tons/acre/year. The erosion rate for pasture was set 1.1 tons/acre/year, which was the statewide average erosion rate for pasture from the 1997

National Resources Inventory (NRI). The NRI was conducted and published by the USDA National Resources Conservation Service (NRCS 2000). Erosion rates for barren land were not available, so barren land was assumed to have an erosion rate that is similar to cropland. The erosion rate for barren land was set to 3.4 tons/acre/year, which was the statewide average erosion rate for cropland from the 1997 NRI.

The tons of sediment per year were multiplied by a mercury concentration of 0.16 mg/kg to estimate mercury load associated with soil erosion in the Spring Lake watershed. Soil mercury concentrations have not been measured extensively in Spring Lake watershed. Soil mercury concentrations that have been measured in Arkansas ranged from 0.1 mg/kg to 0.16 mg/kg.

Table 4.4 Existing mercury load to Spring Lake from erosion

Land Use	Area, m ²	% of Area	Erosion rate, Ton/acre/yr	Sediment, Ton/yr	Total soil mercury load ^a , g/yr	Geologic mercury load ^b , g/yr	Deposited mercury load ^c , g/yr
Forest	43,915,921	98.8	0.2	2,170	315	118	197
Pasture	212, 810	0.5	1.1	58	8	3	5
Barren	812	0.002	3.4	0.7	0.1	0.04	0.06
Total	44,129,543	99		2,229	324	121	202

a. Soil mercury concentration 0.16 mg/kg

b. Soil mercury from erosion of underlying rock equivalent to 0.06 mg/kg

c. Soil mercury from atmospheric deposition equivalent to 0.1 mg/kg

These soil mercury concentrations are consistent with soil mercury concentrations measured in other forest and alluvial soils (Kabata-Pendias and Pendias 1985). Because soils are produced, in part, from the weathering of the underlying geologic material, a geologic mercury contribution to soil mercury was estimated. Therefore, the tons of sediment per year were multiplied by a mercury concentration of 0.06 mg/kg to obtain the mercury in g/yr due to geologic sources (Table 4.4). The 0.06 mg/kg was the mean mercury concentration for Pennsylvanian formations reported in Stone et al. (1995). In addition, mercury atmospheric deposition over the past several decades, if not centuries, has also contributed mercury to the watershed soils. While some of this mercury was likely re-emitted to the atmosphere, some of this previously deposited mercury would sorb to the soils and be transported to Spring Lake. This portion of the soil erosion mercury load could be affected by reduced mercury emissions and atmospheric deposition. The mercury load due to geologic sources was subtracted from the total

soil erosion mercury load to estimate the mercury load from historical atmospheric deposition to the watershed.

4.3.2 Allowable Mercury Load

The total allowable mercury load for Spring Lake (i.e., the TMDL) was calculated based on the existing load and an assumed linear relationship between mercury loads to the lake and mercury concentrations in fish tissue. In other words, it was assumed here that reducing the mercury loads to the lake by a factor of 2 (for example) would eventually result in a reduction of mercury concentrations in fish tissue by the same factor. This relationship is consistent with steady-state assumptions and the use of bioaccumulation factors, and has been demonstrated in field experiments in the Florida Everglades (Atkeson et al. 2003). Based on this assumption, the TMDL was calculated as the existing mercury load (0.91 g/day) multiplied by a factor equal to 1.00/1.05 (the target fish tissue concentration divided by the measured fish tissue concentration). This yielded a TMDL of 0.86 g/day for Spring Lake.

The WLA for point source contributions was set to zero because there are no point source discharges to Spring Lake. Ten percent of the TMDL (0.09 g/day) was set aside as an explicit MOS. The remaining portion of the TMDL (0.77 g/day) was assigned to the load allocation LA for nonpoint sources. The percent reduction needed for nonpoint source loads was calculated by taking the difference between the existing nonpoint source load (0.91 g/day) and the LA (0.77 g/day), and dividing it by the existing nonpoint source load. The TMDL components and nonpoint source reduction are summarized in Table 4.5.

Table 4.5 Spring Lake TMDL for mercury.

	Mercury Load (g/day)
Wasteload Allocation	0.00
Load Allocation	0.77
Margin of Safety	0.09
Total Maximum Daily Load	0.86

4.4 Reduction to Achieve EPA Methyl Mercury Criterion

As a matter for consideration, the reduction of Spring Lake mercury load that would be required to reduce fish tissue mercury concentrations to the EPA methyl mercury criterion of 0.3 mg/kg was also calculated. Mercury in Spring Lake largemouth bass would need to be reduced 71% to meet the 0.3 mg/kg criterion. A 71% reduction of the Spring Lake mercury load would not be possible because the anthropogenic load (atmospheric deposition and soil erosion) is only about 63% of the total mercury load (see Table 4.1.).

5.0 MARGIN OF SAFETY, SEASONAL VARIATIONS AND CRITICAL CONDITIONS

5.1 Margin of Safety

MOS accounts for any lack of knowledge or uncertainty concerning the relationship between load allocations and water quality. In this case, it accounts for uncertainty and variability related to fish tissue mercury concentrations, estimates of atmospheric loading and application of the principal of linearity. Although the proposed approach has not been proven, and monitoring and sampling information are not available, it is assumed that a reduction in loading will result in reductions in fish tissue body burden. This TMDL incorporates an explicit MOS factor of 10%.

5.2 Seasonal Variations and Critical Conditions

Wet deposition is greatest in the winter and spring seasons. Mercury loads fluctuate based on the amount and distribution of rainfall, and variability of localized and regional/global sources. While an average daily load is established here, the average annual load is of greatest significance because mercury bioaccumulates over the life of the fish and the resulting risk to human health from fish consumption is a long-term phenomenon. Thus, daily or weekly inputs are less meaningful than total annual loads over many years. The use of annual loads allows for integration of short-term and seasonal variability. Inputs should continue to be estimated through wet deposition and additional monitoring.

Mercury methylation is expected to be highest during the summer. High temperatures promote biological activity and reservoirs are stratified with anoxic hypolimnions. Based on the enhanced methylation and higher predator feeding rates during this period, mercury bioaccumulation is expected to be greatest during the summer. However, given the long depuration times for fish and relatively mild winters in Arkansas, seasonal changes in fish tissue mercury body burden are expected to be relatively small. Inherent variability of mercury concentrations between individual fish of the same and/or different size categories is expected to be greater than seasonal variability.

6.0 OTHER RELEVANT INFORMATION

As rules and standards pursuant to the Clean Air Act have been developed, proposed, and promulgated since 1990, compliance by emitting sources as well as actions taken voluntarily have already begun to reduce emissions of mercury to the air across the US. The EPA expects a combination of ongoing activities will continue to reduce mercury emissions to the air over the next decade. The EPA currently regulates emissions of mercury and other hazardous air pollutants under the maximum achievable control technology (“MACT”) program of Section 112 of the Clean Air Act, and under a corresponding new source performance standard (“NSPS”) program under Sections 111 and 129 of the Act. Section 112 authorizes the EPA to address categories of major sources of hazardous air pollutants, including mercury, by issuing emissions standards that, for new sources, are at least as stringent as the emissions control achieved by the best performing similar source in the category, and, for existing sources, are at least as stringent as the average of the best performing top 12% (or 5 facilities whichever is greater) of similar sources. The EPA may also apply these standards to smaller area sources, or choose to apply less stringent standards based on generally available control technologies (“GACT”). Sections 111 and 129 direct the EPA to establish MACT-equivalent standards for each category of new and existing solid waste incineration units, regulating several specified air pollutants, including mercury. In addition, in 1996 the US eliminated the use of mercury in most batteries under the Mercury Containing and Rechargeable Battery Management Act. This action is reducing the mercury content of the waste stream, which is further reducing mercury emissions from waste combustion. In addition, voluntary measures to reduce use of mercury containing products, such as the voluntary measures committed to by the American Hospital Association, also will contribute to reduced emissions from waste combustion.

Based on the EPA’s National Toxics Inventory, the highest emitters of mercury to the air include coal-burning electric utilities, municipal waste combustors, medical waste incinerators, mercury cell chlor-alkali plants, and hazardous waste combustors. EPA has issued a number regulations under Sections 111, 112, and 129 to reduce mercury pollution from several of these

source categories. Relevant regulations that EPA has established to date under the Clean Air Act include, among others, those listed below.

1. The source category of municipal waste combustion (MWC) emitted about 20% of total national mercury emissions into the air in 1990. EPA issued final regulations under Sections 111 and 129 for large MWCs on October 31, 1995. Large combustors or incinerators were required to be in compliance with the rule by December 2000. These regulations reduce mercury emissions from these facilities by about 90% from 1990 emission levels.
2. Medical waste incinerators (MWIs) emitted about 24% of total national mercury emissions into the air in 1990. EPA issued emission standards under Sections 111 and 129 for MWIs on August 15, 1997. This rule reduced mercury emissions from MWIs by about 97% from 1990 emission levels.
3. Hazardous waste combustors (HWCs) emitted about 2.5% of total national mercury emissions in 1990. In February 1999, EPA issued emission standards under Section 112 for these facilities, which include incinerators, cement kilns, and lightweight aggregate kilns that burn hazardous waste. This reduced mercury emissions from HWCs by more than 50% from 1990 emission levels.
4. Mercury cell chlor-alkali plants emitted about 4.5% of total mercury emissions to the air in 1994-1995. In December 2003 EPA issued mercury emission standards for these facilities under Section 112. When fully implemented. These standards will reduce mercury emissions from mercury cell chlor-alkali plants by about 94%.
5. Coal-burning electric utilities emitted the greatest percentage of total national mercury emissions to the air in 1990. In 1999 they emitted over 40% of the total national mercury emissions to the air. In March 2005 EPA issued the Clean Air Interstate Rule, and the Clean Air Mercury Rule. When fully implemented these rules will reduce mercury emissions from coal-burning electric utilities by nearly 70% from 1999 emissions levels.

These promulgated regulations when fully implemented and considered together with actions discussed above that will reduce the mercury content of waste are expected to reduce national mercury emissions caused by human activities by about 50% from 1990 levels.

It is possible that the cumulative effect of additional standards and voluntary actions will reduce mercury emissions from human activities in the US by more than 50% from 1990 levels. In 1999, mercury emissions had already dropped 45% from 1990 levels. Mercury deposition modeling of the influence of the Clean Air Interstate Rule suggests that mercury deposition in the Spring Lake watershed could be reduced as much as 5 ug/m² by 2020 (EPA 2005b).

There is good evidence that reducing atmospheric deposition loads of mercury can reduce fish tissue mercury concentrations. Results from the METAALICUS project suggest that fish tissue concentrations are most responsive to changes in mercury loads entering a lake through direct deposition to the lake surface (compared to changes in mercury deposition to the watershed that may be transported to the lake) (Blanchfield et al. 2005). Reduction of mercury emissions within Florida is believed to be the cause of a more than 60% decline in mercury concentrations in Everglades fish (Atkeson et al. 2003). EPA study of the benefits of the Clean Air Mercury Rule suggest that the reduction of mercury deposition resulting from the Rule would result, on average, in about a 6% reduction in fish tissue mercury concentrations in Arkansas by 2020 (EPA 2005b). Because the majority of the mercury load to Spring Lake is from the watershed from erosion of previously deposited mercury, the fish mercury concentrations may take decades to decline in response to decreased mercury emissions and deposition (Chen et al. 2005).

The environmental indicators with which to evaluate success will be monitoring of wet deposition rates at the OK99 site and fish tissue mercury concentrations in Spring Lake.

7.0 PUBLIC PARTICIPATION

When EPA establishes a TMDL, federal regulations require EPA to publicly notice and seek comment concerning the TMDL. Pursuant to a May 2000 consent decree, this TMDL was prepared under contract to EPA. After development of the draft version of this TMDL, EPA prepared a notice seeking comments, information, and data from the general public and affected public. No comments, data, or information were submitted during the public comment period. EPA has transmitted the final TMDL to ADEQ for implementation and for incorporation into ADEQ's current water quality management plan.

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APPENDIX A

Maps

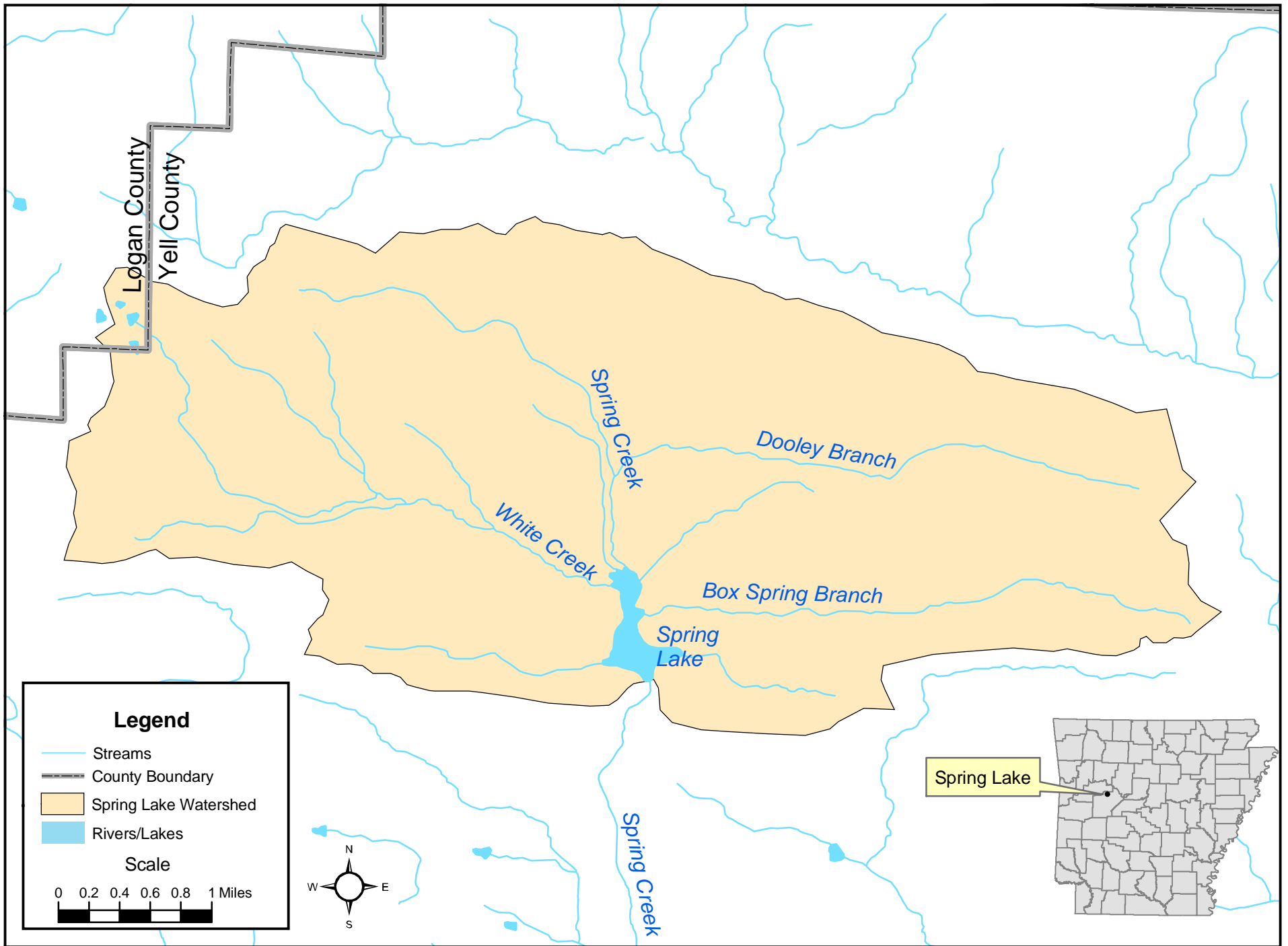


Figure A.1. Watershed Map for Spring Lake

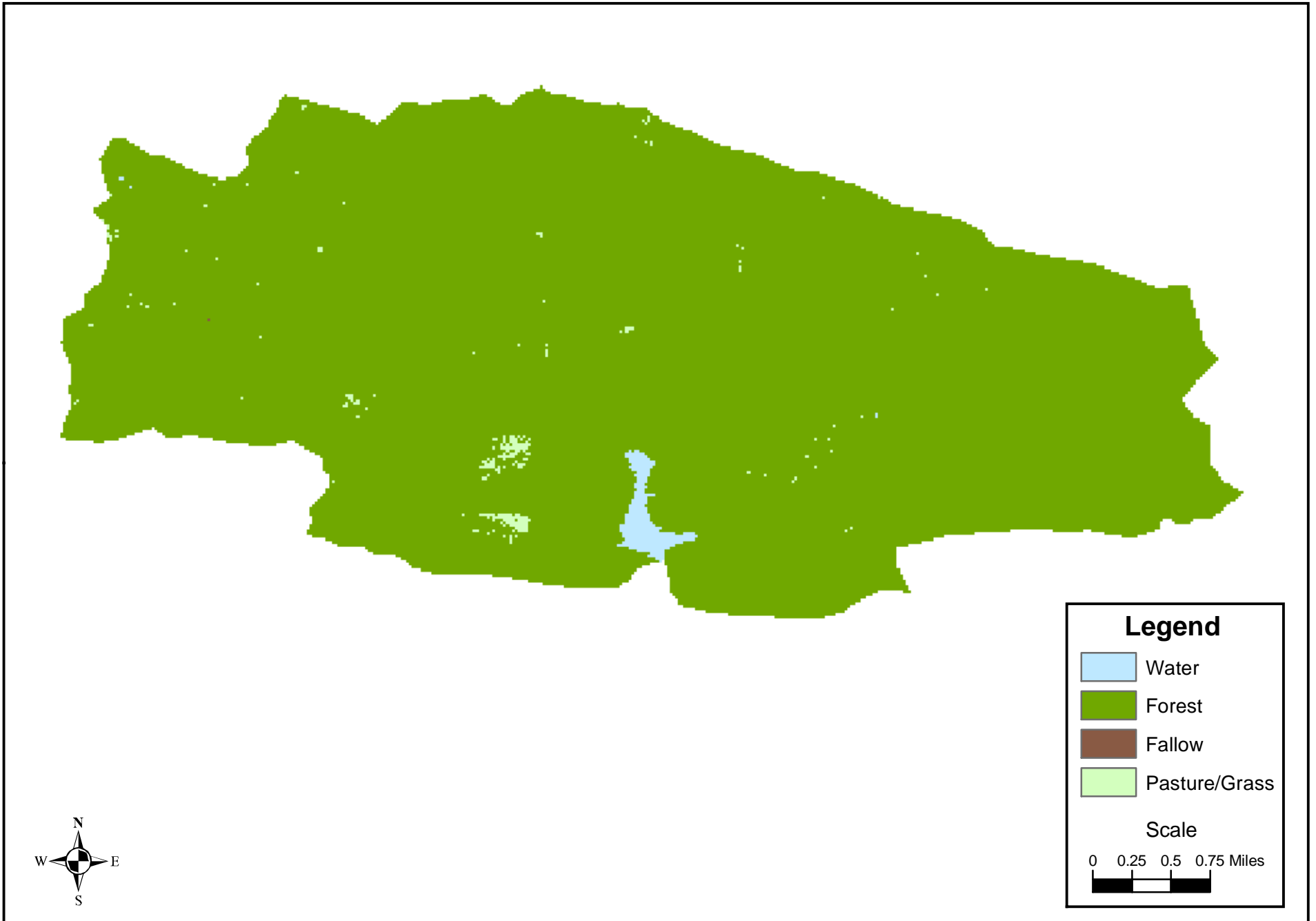


Figure A.2. Land Use Map for Spring Lake

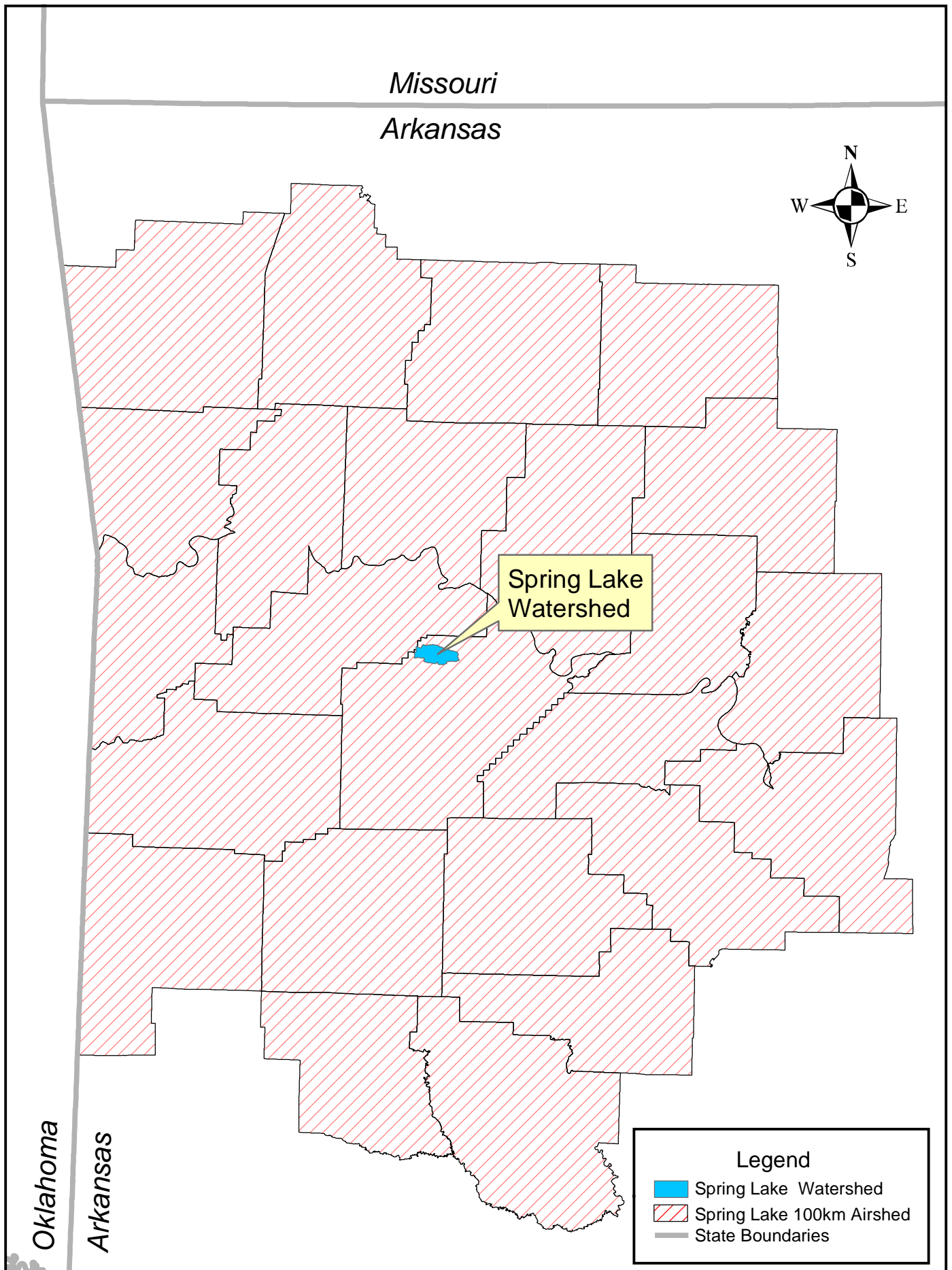


Figure A.3 Airshed boundary for Spring Lake Watershed

APPENDIX B

**Local mercury air emission point sources from 2002
National Emissions Inventory**

Spring Lake Airshed Mercury Emissions

County	SCC No.	SCC Description			Total Mercury Emissions, Ton/yr	Total Mercury Emissions, kg/yr	Particulate Divalent, %	Gaseous Divalent, %	Elemental Gaseous, %	Hg(II) Emissions, kg/yr
Franklin	10100401	External Combustion Boilers	Electric Generation	Residual Oil	9.26E-05	9.26E-02	20	30	50	4.63E-02
Conway	10200903	External Combustion Boilers	Industrial	Wood/Bark Waste	1.00E-01	1.00E+02	20	30	50	5.00E+01
Pope	10200904	External Combustion Boilers	Industrial	Wood/Bark Waste	2.46E-05	2.46E-02	20	30	50	1.23E-02
Hot Springs	30500311	Industrial Processes	Mineral Products	Brick Manufacture	6.97E-03	6.97E+00	10	10	80	1.39E+00
Johnson	30500311	Industrial Processes	Mineral Products	Brick Manufacture	2.34E-03	2.34E+00	10	10	80	4.69E-01
Sebastian	30500314	Industrial Processes	Mineral Products	Brick Manufacture	1.37E-03	1.37E+00	10	10	80	2.73E-01
Saline	39999999	Industrial Processes	Miscellaneous Manufacturing Industries	Miscellaneous Industrial P	3.39E-04	3.39E-01	20	30	50	1.69E-01
Hot Springs	31000411	Industrial Processes	Oil and Gas Production	Process Heaters	2.27E-07	2.27E-04	10	10	80	4.54E-05
Pulaski	31000411	Industrial Processes	Oil and Gas Production	Process Heaters	8.40E-06	8.40E-03	10	10	80	1.68E-03
Sebastian	30300908	Industrial Processes	Primary Metal Production	Steel Manufacturing	9.89E-02	9.89E+01	10	10	80	1.98E+01
Conway	30700105	Industrial Processes	Pulp and Paper and Wood Products	Sulfate (Kraft) Pulping	8.00E-02	8.00E+01	20	30	50	4.00E+01
Conway	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	2.25E-06	2.25E-03	10	10	80	4.49E-04
Crawford	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	6.40E-06	6.40E-03	10	10	80	1.28E-03
Faulkner	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	6.49E-06	6.49E-03	10	10	80	1.30E-03
Garland	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	2.36E-07	2.36E-04	10	10	80	4.71E-05
Logan	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	4.66E-07	4.66E-04	10	10	80	9.33E-05
Pike	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	3.19E-07	3.19E-04	10	10	80	6.38E-05
Polk	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	3.69E-07	3.69E-04	10	10	80	7.38E-05
Pope	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	1.91E-06	1.91E-03	10	10	80	3.83E-04
Pulaski	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	3.62E-05	3.62E-02	10	10	80	7.24E-03
Saline	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	1.54E-05	1.54E-02	10	10	80	3.07E-03
Scott	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	5.02E-07	5.02E-04	10	10	80	1.00E-04
Sebastian	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	4.22E-06	4.22E-03	10	10	80	8.44E-04
Van Buren	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	1.93E-06	1.93E-03	10	10	80	3.86E-04
Washington	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	1.95E-05	1.95E-02	10	10	80	3.89E-03
Yell	50100402	Waste Disposal	Solid Waste Disposal - Government	Landfill Dump	2.92E-06	2.92E-03	10	10	80	5.83E-04

TOTAL = 2.90E-01 290.13 112.16

= SCC speciation
 = MACT speciation based on SCC description